WR

CHARTER MARK

The Patent Office

09/9[illegible]6816

PCT/GB00/01033

REC'D 04 MAY 2000

WIPO PCT

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

GB00/01033

(4)

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed M Cooke

Dated 17 APR 2000

**PRIORITY DOCUMENT**

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

**Patents Form 1/77**

The Patent Office

Patents Act 1977
(Rule 16)

9906299.4

THE PATENT OFFICE
18 MAR 1999
RECEIVED BY HAND

19MAR99 E435362-1 002040
P01/7700 0.00 - 9906299.4

# Request for grant of a patent

*(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)*


The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH


1. Your reference: PDG/IK/21302

2. Patent application number *(The Patent Office will fill in this part)*

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*:
   BRITISH BROADCASTING CORPORATION
   BROADCASTING HOUSE
   LONDON W1A 1AA
   UNITED KINGDOM

   Patents ADP number *(if you know it)*: 349555001

   If the applicant is a corporate body, give the country/state of its incorporation: GB

4. Title of the invention: WATERMARKING

5. Name of your agent *(if you have one)*: MATHYS & SQUIRE

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*:
   100 GRAYS INN ROAD
   LONDON WC1X 8AL
   UNITED KINGDOM

   Patents ADP number *(if you know it)*: 1081001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

| Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|
| | | |

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

| Number of earlier application | Date of filing *(day / month / year)* |
|---|---|
| | |

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   *a) any applicant named in part 3 is not an inventor, or*
   *b) there is an inventor who is not named as an applicant, or*
   *c) any named applicant is a corporate body.*
   *See note (d))*

   YES

## Watermarking

The invention relates to embedding an invisible mark into either a still picture or a sequence of moving pictures; this may be used to assist in detection of copying or identification of the originator of material or for transmitting hidden data. A watermark is a mark or data sequence that is embedded substantially invisibly into a picture for helping to identify the originator or the intended recipient of the picture or to detect tampering.

It has been considered to modulate a watermark onto sample mean values, also known as DC-values, but this has tended to result in unacceptable picture distortion.

Yeung and Mintzer [Journal of Electronic Imaging 7(3), 578-591 (July 1998)] proposed a watermarking system in which a watermark is applied to DC coefficients of a JPEG compressed image. This is stated to produce satisfactory results for an RGB image but there was some noticeable degradation (blockiness) observed when the watermark was applied to luminance values. Investigations by the inventor have suggested that such a technique is unsuited to high quality image reproduction or broadcast quality motion video marking as the artifacts tend to become too visible, and one is generally dealing with a luminance signal rather than an RGB signal.

Qiao and Nahrstedt [IEEE International Conference on Multimedia Computing and Systems, Austin Texas USA, 28th June - 1st July 1998] proposed a watermarking technique in which a watermark is applied to DCT coefficients in the transform domain. The technique is suitable for MPEG coded video. This disclosure notes that problems can arise when a watermark is applied to both DC and AC coefficients and suggests that no watermark should be applied to the DC coefficients. A drawback of this method is that the watermark must be applied in the transform domain and this may require transformation of an image, thereby increasing the complexity of the method.

each of which adjustment factors is a function of a local estimate of visibility of the watermark within the picture and which is a function of the picture sample values (and substantially independent of the watermark values), it has been found that, surprisingly, the watermark information can be reliably embedded in the picture without causing unacceptable distortion to the picture. The embedded watermark value may then change the local mean or DC-values of the subset of pixels in which it is embedded, rendering detection simple and reliable.

It will be appreciated that this method may result in a watermarked picture in which watermark information is barely present or even not present at all in certain regions of the picture where the estimate of visibility suggests that the presence of the watermark is likely to cause visible distortions to the picture.

Preferably the magnitude of adjustment factors is determined from the picture sample values based on an estimate of visibility, preferably from the local variance. This enables the watermark values to be concealed effectively. There will be a plurality of values calculated for each subset, to take into account picture variation, and there is preferably an independently determined adjustment value for each picture sample, although calculation of neighbouring adjustment factors may involve some overlap to reduce calculation.

The sign of the adjustment factors is preferably a function of the watermark values, the watermark values preferably comprising a binary sequence of 0 and 1, being encoded respectively as positive and negative signs respectively, or vice versa. By changing the sign, a robust coding scheme is provided, the magnitude of the change not being critical in detecting the watermark and hence being adjustable to allow the watermark to be kept substantially invisible. Alternatively, the magnitude may be adjusted in steps; this may increase the available data capacity but may increase visibility, reduce robustness or increase complexity.

In a development, since measures of visibility may be determined from the watermarked picture which should correspond substantially to the originally

partitions the picture into blocks, for example JPEG or MPEG coding, the grid preferably corresponds to blocks or groups of blocks of the coding algorithm. This may enable efficient processing and may also ensure that the watermark is reliably carried (more so than if individual watermark values were assigned to pixels in different blocks).

It has been found that if each subset comprises a block of at least about 4 by 4 samples (or 16 samples if non-rectangular grouping is used), this provides a much higher degree of robustness against a variety of attacks than a comparative example in which significantly fewer (or only one) picture samples per watermark value are employed. Preferably, blocks of at least about 8 by 8 samples (or similar size, at least about 64 samples if non-rectangular grids) are used, more preferably, at least for broadcast quality images, blocks of at least about 8 by 16 (preferably 8 vertically, 16 samples horizontally).

Watermark values may be assigned to substantially the whole of a picture. This may increase the dimension of the watermark and make unauthorised copying and detection more difficult. However, a repeating watermark may be used, or certain portions of the picture may be left blank.

The watermark may comprise a substantially static component and a variable component, the static component enabling the watermark to be positively identified, and the variable component carrying additional information, for example one or more of picture (or programme) title, date, author, originator, intended recipient, copying permissions, equipment or recording or coding conditions, user definable data and the like. Looked at another way, data may be carried with the watermark. In the case of a moving picture sequence, a separate hidden data stream may be carried, some of the watermark assisting in alignment and framing and the remainder carrying user data. If the application is such that the source and framing of the sequence can be guaranteed, then no static watermark may be needed for synchronisation, and the whole of the watermark may in fact comprise variable user information.

The invention further provides a method of testing for the presence of a watermark as set out in Claim 27 and the preferred features set out in Claims 28 to 37.

Further aspects are set out in Claims 38, 39 and 40 and 41.

An embodiment of the invention will now be described by way of example, with reference to the accompanying drawings in which:-

Fig. 1 shows a general outline of a watermarking system;

Fig. 2 illustrates partition of a picture into square cells;

Fig. 3 schematically illustrates an example of calculation of variance for current sample $s_n$ and its neighbouring samples that belong to $B_n$; and

Fig. 4 illustrates partition of a picture into square cells that carry either a watermark sample or a data bit.

Referrring to Fig. 1, the watermark is embedded into the original signal, resulting in the watermarked signal. The watermarked signal may be changed by friendly attacks that are caused by transmission techniques e.g. data compression or by hostile attacks that deliberately attempt to remove the watermark. Therefore, the signal instead of feeds the input of the watermark-detector. The detector outputs a binary decision which indicates if a given watermark is present in the input signal or not.

In this description restricted watermarking means that the original signal is also needed as an input to the watermark-detector. In this case watermark detection is restricted to users who are in possession of the original signal. Unrestricted watermarking means that the original signal is not needed during detection. Both cases will be addressed.

The watermark is a zero-mean (to prevent a change in global mean [average brightness] of the signal after watermarking) white noise random signal that is chosen independently from the original signal and difficult-to-predict for an attacker. The role

Averaging over all samples gives the mean value

(4) $$\overline{\text{var}}\frac{1}{N}\cdot\sum_{n=1}^{N}\text{var}(n)$$

Additionally, the positive modulation index *q* is introduced for allowing a global control of the energy of the modulated watermark, resulting in the magnitude

(5) $$\alpha^2(n)=\begin{cases}\dfrac{2\cdot\text{var}(n)+\overline{\text{var}}}{\text{var}(n)+2\cdot\overline{\text{var}}} & \text{if } \text{var}(n)>th_{flat}\\ 0 & \text{if } \text{var}(n)\leq th_{flat}\end{cases}$$

As a consequence of eq. (5) no watermark information is embedded into flat areas that are detected with a threshold $th_{flat}$.

Eqn.(5) is one example for the calculation of the magnitude $\alpha^2(n)$ and more sophisticated models of the human visual system can be applied in combination with the embedding method that is specified in eq. (2).

After transmission and possible attacks the received signal $\check{s}_w$ is partitioned into cells of appropriate shape and size corresponding to the embedding procedure. For each cell a sample mean value is calculated, hereafter called DC-value. The DC-value of the k-th cell is calculated as

(6) $$DC(k)=\frac{1}{|C_k|}\cdot\sum_{n\in C_k}\check{s}_w(n),$$

detector has the option to exclude flat areas during the evaluation of eq. (9).

In restricted watermarking it is easier to align the sampling grid of the received signal $\check{s}_w$ relative to the sampling grid that was used for embedding the watermark. This can be done by comparing $\check{s}_w$ with the original signal $s$ which also allows compensation for geometric distortions such as scaling or rotation. In unrestricted watermarking the sampling grids can be aligned by a search for maximum correlation among a set of horizontal and vertical offset values that are applied to the sampling grid of $\check{s}_w$. As every watermark sample is spread over one cell perfect alignment of the sampling grids is not needed for obtaining a good correlation. This property improves significantly the robustness against attacks that re-sample the picture including geometric attacks that introduce an unnoticeable amount of distortion. Additionally, the cell size and the cell shape can be adapted for improving the robustness against specific types of geometric distortions. Rotation, cropping or scaling by a noticeable amount can be handled by hypothesis testing which however results in a computational intensive search for maximum correlation.

A common method for increasing the capacity of the hidden data channel is to partition the picture into sub-pictures and to apply the above watermarking method to each sub-picture. Another method for increasing the data capacity shall now be exemplified for a square cell shape, see Fig. 4. The white cells are used for the watermarking method as described above. Firstly, the watermark is detected from the white cells at the receiver. This also allows synchronisation and alignment of the sampling grid. Secondly, one data bit is detected from each dark cell as follows. For the k-th cell the DC-values of eqs. (6)-(8) are calculated. In restricted watermarking, the sign of the difference

$$\Delta DC(k) = (DC(k) - DC_{ori}(k))$$

signals the data bit and in unrestricted watermarking the sign of the difference

$$\Delta DC(k) = (DC(k) - DC_{pred}(k))$$

signals the data bit. At the transmitter the data bit is embedded similar to eqs. (2)-(5), the watermark sample is replaced with the antipodal data bit in eq. (2). As no

**CLAIMS:**

1. A method of embedding a watermark signal comprising a series of watermark values in a picture signal comprising a series of picture sample values, the method comprising adjusting picture sample values based on watermark values, characterised in that adjusting comprises, for each watermark value:

combining the watermark value with a respective subset of the picture sample values using a plurality of adjustment factors, each adjustment factor being based on a local estimate of the visibility of the watermark at a corresponding picture sample location.

2. A method according to Claim 1 wherein the magnitude of each adjustment factor is a function of the picture sample values, preferably based on the localised variance of the picture sample values.

3. A method according to Claim 1 or Claim 2, wherein the sign of each adjustment factor is a function of the watermark values.

4. A method according to any preceding claim, wherein combining comprises adding an adjustment factor to each picture sample value.

5. A method according to any preceding claim wherein the picture sample locations for each said subset corresponding to a given watermark value are substantially adjacent.

6. A method according to Claim 5, wherein a grid dividing the picture into a plurality of regions is defined and wherein each said subset comprises picture samples corresponding to a respective region of the grid.

7. A method according to Claim 6, wherein the grid is substantially rectangular.

can be controlled.

18. A method according to any preceding claim wherein said adjustment factors are assigned a value substantially equal to zero for regions having a measure of variance below a predetermined threshold.

19. A method according to any preceding claim for embedding a watermark in a sequence of pictures corresponding to a motion video sequence, wherein the subsets to which watermark values are applied vary from picture to picture.

20. A method of embedding a watermark within a sequence of pictures corresponding to a motion video sequence wherein the watermark is combined with picture sample values characterised in that the method of combining varies from picture to picture to reduce the appearance of static artefacts in the sequence.

21. A method according to Claim 19 or 20, wherein the watermark is embedded in some but not all pictures of the sequence, preferably wherein at most one in two pictures are watermarked.

22. A method according to Claim 19, 20 or 21, wherein the pattern of picture sample values with which watermark values are combined varies from picture to picture.

23. A method according to Claim 22, wherein embedding the watermark includes defining a grid dividing the picture into regions and wherein at least one characteristic of the grid, for example shape, size or alignment, is varied between pictures of the sequence.

24. A method according to any preceding claim further comprising communicating or storing the watermarked picture together with information to assist in identifying the watermark.

the reference or estimated local mean values from local mean values determined for the received picture signal to give a difference signal.

33. A method according to any of Claims 30 to 32 wherein a grid is defined dividing the received signal into regions corresponding to allocation of watermark values, wherein local mean values are determined for each of said regions.

34. A method according to any of Claims 27 to 33 further comprising deriving a series of data values from the received picture signal.

35. A method according to Claim 32, 33 and 34 wherein the data sample values are determined based on the sign of the difference signal in regions corresponding to allocation of data values.

36. A method according to any of Claims 27 to 35 wherein said correlating is performed for a plurality of offsets and the offset giving the maximum correlation is determined to give a measure of the position of the watermark within the picture.

37. A method according to any of Claims 27 to 36 wherein correlating is performed taking into account possible effects of picture processing operations, for example rotation, scaling, shifting, cropping or re-sampling operations.

38. A watermarked picture, a sequence of pictures, a signal or data storage means containing a picture having a watermark embedded therein by a method according to any of Claims 1 to 26.

39. Apparatus arranged to perform a method according to any of Claims 1 to 37.

40. A method of decoding data in a picture signal comprising determining local mean values of picture samples corresponding to regions of the picture in which data is carried; comparing said local mean values to estimated or reference local mean values for said regions in the absence of the data, and determining a data value from

## ABSTRACT


### Watermarking

A watermarking system and method is proposed for still or moving pictures in which a watermark is embedded robustly and simply into DC-values, but without causing unacceptable visible picture degradation. The watermark is secure and can be readily detected, and the method can be used to convey additional data. Also disclosed is a method for watermarking a sequence of pictures in which the visibility of artefacts is reduced.

Fig. 1

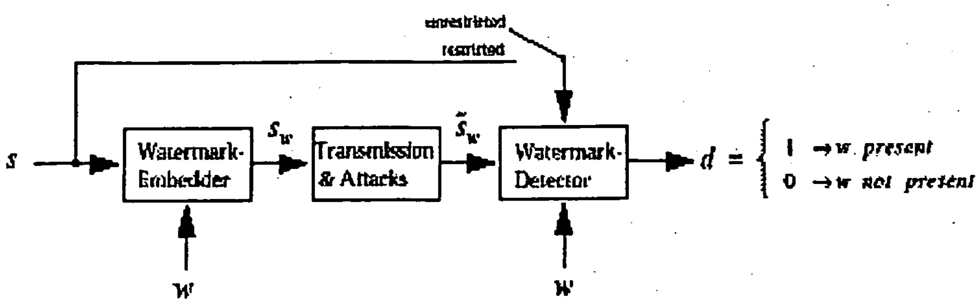



Fig. 2

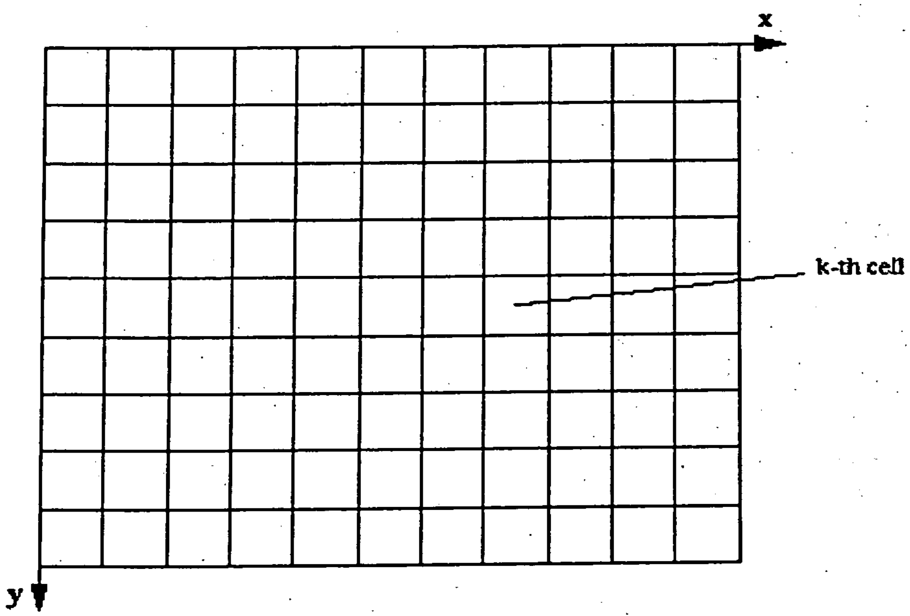
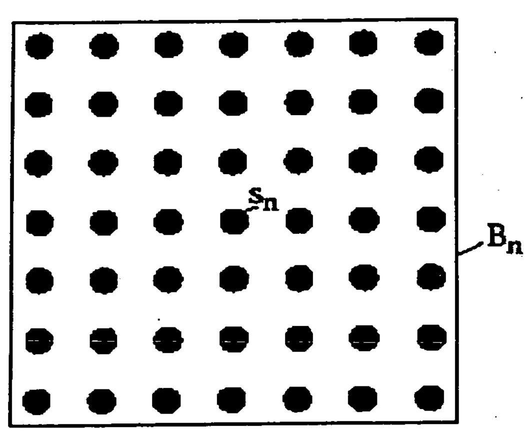



Fig. 3



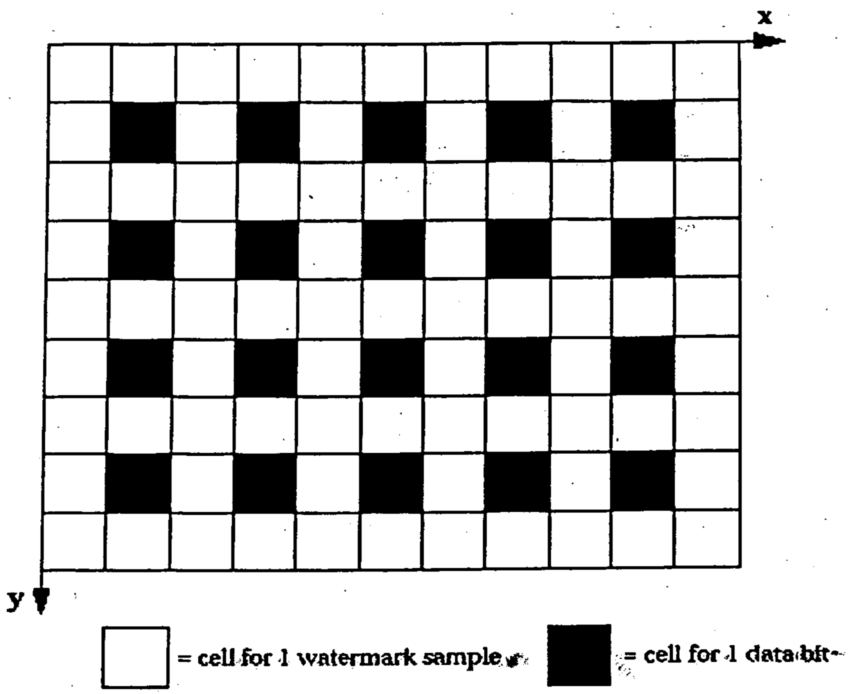



Fig. 4